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Original Article

Development of clinical prediction models for outcomes of complicated intra-abdominal infection

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Abstract

Background: Complicated intra-abdominal infections (cIAIs) are associated with significant morbidity and mortality. The aim of this study was to describe the clinical characteristics of patients with cIAI in a multicentre study and to develop clinical prediction models (CPMs) to help identify patients at risk of mortality or relapse.

Methods: A multicentre observational study was conducted from August 2016 to February 2017 in the UK. Adult patients diagnosed with cIAI were included. Multivariable logistic regression was performed to develop CPMs for mortality and cIAI relapse. The c-statistic was used to test model discrimination. Model calibration was tested using calibration slopes and calibration in the large (CITL). The CPMs were then presented as point scoring systems and validated further.

Results: Overall, 417 patients from 31 surgical centres were included in the analysis. At 90 days after diagnosis, 17.3 per cent had a cIAI relapse and the mortality rate was 11.3 per cent. Predictors in the mortality model were age, cIAI aetiology, presence of a perforated viscus and source control procedure. Predictors of cIAI relapse included the presence of collections, outcome of initial management, and duration of antibiotic treatment. The c-statistic adjusted for model optimism was 0.79 (95 per cent c.i. 0.75 to 0.87) and 0.74 (0.73 to 0.85) for mortality and cIAI relapse CPMs. Adjusted calibration slopes were 0.88 (95 per cent c.i. 0.76 to 0.90) for the mortality

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model and 0.91 (0.88 to 0.94) for the relapse model; CITL was −0.19 (95 per cent c.i. −0.39 to −0.12) and − 0.01 (− 0.17 to −0.03) respectively.

Conclusion: Relapse of infection and death after complicated intra-abdominal infections are common. Clinical prediction models were developed to identify patients at increased risk of relapse or death after treatment, although these require external validation.

Introduction

Complicated intra-abdominal infections (cIAIs) are defined as intra-abdominal infections that have extended beyond the hollow viscus of origin into the peritoneal space and are associated with either abscess formation or peritonitis[1]. One in five patients with cIAI fail treatment[2,3], and in high-risk groups such as the elderly and those with severe sepsis, the mortality rate is up to 50–80 per cent[4,5].

Treatment of cIAIs includes source control and administration of antibiotic therapy. Guidelines[6] recommend that source control procedures should be the least invasive method capable of obtaining adequate source control, and that antibiotics be limited to 4–7 days. Despite current recommended treatment strategies, patients still suffer high rates of relapse and mortality after cIAI treatment. Additional strategies are therefore required to help optimize the care of patients with cIAI. Use of clinical prediction models may be able to optimize care by identifying patients with the highest risk of cIAI relapse or death. Currently, disease-specific prediction models for cIAI exist, which are designed to be used in the perioperative period in patients undergoing source control, but are rarely used in routine clinical care. These models identify patients at the greatest risk of death, so that the aggressiveness of treatment can be decided early[4,7]. However, they are restricted to patients who undergo a source control procedure. Additionally, they do not predict the risk of relapse, one of the most common adverse events after cIAI treatment.

The aim of this study was to undertake a multicentre observational study to describe the population of patients with cIAI in the UK, clinical prediction models (CPMs) were then developed to determine the probability of relapse and death in patients with cIAI, managed with and without source control procedures.

Methods

A multicentre observational study was performed between August 2016 and February 2017. The study was classed as a service evaluation, registered at participating sites, and information governance approval was obtained. Data were collected prospectively and recorded using Excel® (Microsoft, Redmond, WA, USA), and anonymized before centralization.

Centre eligibility

All hospitals in the UK were eligible to enter patients. Invitations to participate were distributed via trainee-led, surgical and infection research collaboratives.

Patient eligibility

Patients were screened prospectively on inpatient wards, including ICUs. To reduce bias, investigators were asked, where possible, to recruit consecutively identified eligible patients. Patients were included if they were aged ≥18 years with a confirmed cIAI. Patients were excluded if they had a cIAI diagnosed within the previous year, or their cIAI was diagnosed more than 7 days before screening, to ensure that only primary episodes of cIAI were included and that included patients were not biased towards having more complicated disease. Patients were also excluded if they had primary appendicitis managed surgically, active necrotizing pancreatitis (not excluding discrete pancreatitis infections such as abscesses or infected pseudocysts), primary (spontaneous) bacterial peritonitis, and continuous ambulatory peritoneal dialysis peritonitis, as these were considered to be distinct clinical conditions with specific management protocols.

Outcome measures

The major outcomes assessed were the presence of cIAI relapse and all-cause mortality, both within 90 days of cIAI diagnosis. These same outcomes were considered when generating the CPMs. Additional outcome measures under investigation included the duration of hospital stay, time to relapse or death, and time to clinical improvement.

Definitions

A diagnosis of cIAI was based on: a combination of radiological and clinical features consistent with cIAI including a fluid collection and/or perforated viscus, a temperature of 38°C or above or less than 35°C, and a neutrophil count greater than 7.5×10^9/l); or intraoperative confirmation of an abscess or perforated abdominal viscus. In addition, the diagnosis was confirmed by a consultant surgeon.

A cIAI relapse could occur only after source control and/or antibiotic therapy to manage the primary cIAI was considered to have been successful. This would be demonstrated by the cessation of antibiotics and there being no further source control procedures planned. The diagnosis of cIAI relapse was made using the same criteria as a cIAI, but could also include probable cIAI, where, in the absence of radiological imaging, no other source was identified and the diagnosis was confirmed by a consultant surgeon as cIAI relapse.

Change of antibiotic treatment due to clinical failure was defined as a change of antibiotic therapy where the clinician collecting the data had determined failure of the previous antibiotic regimen. Where there was failure of primary treatment of the cIAI, the reason was taken as the main factor to which the clinician collecting the data attributed responsibility.

Failure of initial management was defined as the requirement for an additional unplanned source control procedure and/or a change of antibiotics due to either failure of antibiotics or the presence of resistance.

Statistical analysis

CPMs were developed in accordance with the TRIPOD statement[8].

Demographic, clinical, and treatment characteristics of patients who died were compared with those who survived; and details of patients who had a cIAI relapse were compared with those who did not. Categorical data are presented as proportions. Continuous data were tested for normality by visual assessment of the histogram and then summarized as median (i.q.r.) values. Comparisons were tested using the χ^2 test (or Fisher's exact test if appropriate) for categorical data and the Mann–Whitney *U* test for continuous skewed variables.

Multivariable logistic regression was used to develop prediction models to determine which characteristics were associated with death or cIAI relapse. Variables included in the pool of

potential predictors were identified *a priori* based on their clinical importance and likelihood (based on existing evidence) to affect outcomes[4,9]. The variables assessed for potential inclusion in the models for relapse and mortality were: age, sex, underlying pathology, site of cIAI, presence of perforation, presences of collection(s), presence of anastomotic leak, and whether there was failure of initial management. Treatment variables comprising of duration of antibiotic therapy and type of source control procedure performed were also included.

Missing data in the data set were assumed to be missing at random. Multiple imputation via chained equations was therefore undertaken to account for missing data. A set of 20 imputed data sets was created using predictive mean matching, with the outcomes and all variables in the pool of potential prognostic factors included in the imputation procedure[10]. The functional form for continuous variables was assessed via fractional polynomials within each imputed data set. Diagnostic plots were used to check the fit of the imputation models[11]. Variables were selected for inclusion in the final model within each imputed data set via backwards selection with a *P* value of 0.100. Variables that featured in at least 10 of the 20 imputed models were selected for the final model. Pooled odds ratios (ORs) and intercepts were calculated according to Rubin's rule.

Apparent measures of model performance were calculated for the final multiply imputed model. Discrimination was evaluated via the c-statistic, and calibration was assessed via calibration slopes and calibration in the large (CITL). The c-statistics resulting from the imputed data set were pooled via robust methods, and the median of the imputed estimates is therefore presented[12,13]. Calibration was also observed via a calibration plot for each imputed data set separately, and the median of the imputed estimates was provided[13].

Non-parametric bootstrapping was used to estimate optimism, and to examine model stability. In each of 500 bootstrap samples, the entire modelling process, including predictor selection, was repeated, and the apparent model performance (calibration and discrimination in the bootstrap sample) was compared with the performance in the original sample per multiply imputed data set.

The median optimism across all imputed samples was then used to calculate the optimism-adjusted c-statistic and optimism-adjusted calibration slope[14]. Using the latter as a uniform shrinkage factor, all the predictor effects in the final developed model were penalized to account for overfitting[15].

The pool of potential predictors for the backwards selection was any predictor in a final multivariable model for each imputed data set (collection, source control, sex, duration of antibiotics, perforated viscus, and failure of initial management).

The resulting optimism-adjusted prediction models were then presented as a point scoring system by assigning integer scores to the coeffcients[16]. Validation of the integer score was undertaken by evaluating discrimination (c-statistic) and calibration (slope and CITL) for a model containing only the total points scored per person.

Subgroup analysis was performed to determine whether specific microbiological data (when available) were associated with particular clinical outcomes.

Statistical analysis was performed using SPSS® Statistics for Windows® version 22.0 (IBM, Armonk, NY, USA) and R version 3.6.1, (The R Foundation for Statistical Computing, Vienna, Austria).

Results

Data were collected on a total of 463 patients from 31 hospitals in the UK. In total, 417 patients were included in the final analysis; the data provided did not appear to meet the inclusion criteria for 41 patients and five patients died within 72 h of diagnosis. Of the 417 patients, 224 (53.7 per cent) were women, and the mean (s.d.) age was 62.5 (17.7) years. Diverticular disease and postoperative complications were the most common underlying aetiologies in patients with cIAI, accounting for 32.1 and 21.8 per cent of cases respectively. The most common site of infection was the colorectum (56.6 per cent) (*Table 1*).

Radiological features of cIAI included perforated viscus (61.9 per cent), collections (57.7 per cent) and anastomotic leak (10.1 per cent). Of the 232 patients with collections, 75.9 per cent had a single abdominal collection on imaging and 24.1 per cent had multiple collections. The median maximum depth of the largest collection present was 6.0 (i.q.r. 4.0–8.8) cm (*Table 1*).

Patient management

Source control data were missing for 1 patient, of the remaining 416 patients: 30.8 per cent of patients (128 of 416) did not undergo a source control procedure, 14.2 per cent (59 of 416) had percutaneous radiologically guided drainage, and 55.0 per cent (229/416) had a surgical procedure. Surgical resection and proximal diversion was the most frequently performed procedure (101 of 229, 44.1 per cent). A greater proportion of patients who had surgical source control had a perforated viscus: 72.6 per cent compared with 44 per cent of patients who had percutaneous drainage and 52.9 per cent of those who had no source control. Patients undergoing percutaneous drainage were more likely to have a collection (91 per cent *versus* 42.6 per cent of patients undergoing a surgical procedure and 68.5 per cent of patients who had no source control) (*Table S1*).

The median duration of antibiotic treatment in this cohort was 12 (i.q.r. 7–18.5) days. Median antibiotic duration exceeded 7 days irrespective of whether or not patients had a source control procedure. Duration of antibiotic treatment was a

Table 1 Demographics and clinical characteristics of patients with complicated intra-abdominal infection

	No. of patients (n = 417)
Age (years)*	62.5 (17.7)
Sex ratio (F : M)	224 : 193
Site (origin) of cIAI	
Colorectum	236 (56.6)
Small bowel	44 (10.6)
Gastro-oesophagus	41 (9.8)
Biliary	38 (9.1)
Other	31 (7.4)
Appendix	20 (4.8)
Unknown	7 (1.7)
Underlying pathology	
Diverticular disease	134 (32.1)
Postoperative complication	91 (21.8)
Other	77 (18.5)
Perforated peptic ulcer	37 (8.9)
Cancer	30 (7.2)
Inflammatory bowel disease	19 (4.6)
Biliary stones and/or cholecystitis	19 (4.6)
Appendicitis	10 (2.4)
Perforated viscus	231 of 373 (61.9)
Collection present	232 of 402 (57.7)
Single collection	176 of 232 (75.9)
Multiple collections	56 of 232 (24.1)
Depth of biggest collection (cm) (n = 213)†	6.0 (4.0-8.8)
Anastomotic leak	41 of 406 (10.1)

Values in parentheses are percentages unless indicated otherwise; * values are mean(s.d.) and † median (i.q.r.). cIAI, complicated intra-abdominal infection.

median of 10.5 (7–17) days in those who had a surgical procedure, 14 (10–24.5) days in those who had percutaneous drainage only, and 12 (8.5–19) days in those who had no source control procedure. Piperacillin–tazobactam and amoxicillin–clavulanic acid were the antibiotics used most frequently in the treatment of cIAI (*Table S2*).

An additional unplanned source control procedure was performed in 55 per cent of patients who relapsed, compared with 9.8 per cent of patients who did not ($P < 0.001$). Similarly, a change of antibiotics due to perceived clinical failure was required in 37 per cent who relapsed, compared with 14.7 per cent of those who did not ($P < 0.001$).

Clinical outcomes

Overall, 17.3 per cent of patients (72 of 417) had a cIAI relapse and 11.3 per cent (47 of 417) died after 72 h (total mortality including patients who died within 72 h of diagnosis: 52 of 422, 12.3 per cent). The median duration of hospital stay was 17 (i.q.r. 9.0–29.0) days from the date of cIAI diagnosis. The commonest reported cause of cIAI relapse was failure of source control (44 of 72, 61 per cent,). The median time to improvement (defined as apyrexial (temperature below 38°C) for more than 24 h and white cell count lower than 11×10^9/l) from date of diagnosis was 7 (3–14) days. Median time to death or cIAI relapse from diagnosis was 23 (12–51) days and 18 (13–30) days respectively. The mortality rate in patients who had a cIAI relapse was 11 per cent, compared with 10.3 per cent in those who did not have a cIAI relapse ($P = 0.837$). Median duration of antibiotic treatment was longer in patients who survived to day 90 (12 (8–19) days *versus* 9 (6–14.5) days in those who died; $P = 0.007$). Patients who had a cIAI relapse had longer antibiotic treatment for the initial cIAI than those who did not relapse (median 15 (9.75–21.25) *versus* 11 (7–17) days respectively; $P = 0.001$). Median length of hospital stay for primary admission with cIAI was longer in patients who relapsed: 29 (15–49) days compared with 15 (8–25) days in those who did not have a cIAI relapse ($P < 0.001$). Of patients who had collections associated with the cIAI, the rate of relapse in those with multiple collections was 41 per cent (21 of 51) *versus* 19.6 per cent (35 of 179) in those with a single collection ($P = 0.002$).

Model development and model performance measures

Univariable and multivariable models were developed (*Table 2*; *Tables S3 and S4*). After internal validation and imputation, the models showed good performance. The c-statistic was 0.82 (95 per cent c.i. 0.76 to 0.88) for the model predicting mortality and 0.78 (0.71 to 0.84) for the model predicting relapse. The values were 0.79 (0.75 to 0.87) and 0.74 (0.73 to 0.85) respectively after adjusting for model optimism. The calibration plots for the relapse and mortality CPMs are shown in *Figs S1* and *S2*; they show good agreement between observed and predicted probabilities for both models. Calibration slopes were 1.00 (95 per cent c.i. 0.71 to 1.32) for mortality and 1.01 (0.75 to 1.28) for relapse. Calibration slopes adjusted for model optimism were 0.88 (0.76 to 0.90) and 0.91 (0.88 to 0.94) respectively. The CITL was 0.00 (95 per cent c.i. −0.34 to 0.32) for mortality and 0.01 (−0.28 to 0.28) for relapse. After adjustment, the CITL was −0.19 (−0.39 to −0.12) and −0.01 (−0.17 to −0.03) respectively.

For mortality, the predictors included in the parsimonious multivariable logistic regression model were age, cIAI due to cancer, type of source control procedure performed, and the presence of perforated viscus (*Table 2*).

Predictors included in the model for cIAI relapse were presence of a collection, duration of antibiotic treatment, and whether or not there was failure of initial treatment (defined as requiring an additional unplanned source control procedure or a change of antibiotics due to either failure of antibiotics or presence of resistance) (*Table 2*).

The CPMs have been presented using a point scoring system (*Tables 3–6*). The scoring system for mortality predicts probabilities between 0.1 and 70.6 per cent, and that for cIAI relapse predicts probabilities between 0.3 and 52.4 per cent. The scoring system was also validated. In particular, calibration and discrimination were evaluated when the model included the integer score as the only predictor. The c-statistic for mortality was 0.84 (95 per cent c.i. 0.78 to 0.91) and 0.72 (0.65 to 0.79) for relapse. The CITL was 0.00 (95 per cent c.i. −0.41 to 0.38) and 0.00 (−0.30 to 0.29) respectively. These results show good validity for the integer score.

Subgroup analysis

Subgroup analysis of the 273 patients who had samples sent for microbiological culture found that 7.7 per cent had either an ESBL or AmpC producing organism and 21.2 per cent had samples that grew antibiotic-resistant organisms (amoxicillin–clavulanic acid/piperacillin–tazobactam-resistant or ciprofloxacin-resistant Enterobacteriaceae, AmpC or extended-spectrum β-lactamase (ESBL) producers, vancomycin-resistant enterococci and/or methicillin-resistant *Staphylococcus aureus*) Data on organisms were missing for 13 patients. Patients who had antibiotic-resistant bacteria isolated from clinical samples had increased rates of cIAI relapse (33.3 per cent *versus* 19.3 per cent in those with no antibiotic-resistant bacteria isolated; $P = 0.031$), longer duration of antibiotic treatment (median 16.5 (i.q.r. 10–29) *versus* 13 (7–19) days respectively; $P = 0.003$) and longer hospital stay after cIAI diagnosis (median 26.5 (i.q.r. 14.75–42.25) *versus* 15 (9–30) days; $P < 0.001$). The presence of resistant organisms was not associated with mortality: 17.9 per cent in patients who died *versus* 22.8 per cent in survivors ($P = 0.549$).

Discussion

The data collected from this large UK cohort was used to develop clinical prediction models for cIAI relapse or death in patients treated for cIAI. These models have been presented as point scoring systems, providing a range of predicted probabilities that allow clear differentiation between patients' risks of relapse and/or mortality, and so have potential clinical utility with regard to patient management decisions. These models use routinely collected clinical data and so are able to be used readily in standard clinical practice. Model performance tests indicated that both models have good model performance according to discrimination and calibration tests.

Prognostic scores for cIAIs already exist, but these are used primarily to predict mortality. The Manheim Peritonitis Index (MPI) is a disease-specific severity score that has been established previously to be an effective prognostic marker in patients with peritonitis[7]. It is a simple tool to use, and calculates risk of death based on age, sex, presence of organ failure, presence of malignancy, duration of peritonitis, origin of infection, and type of exudate identified during surgery. The use of operative findings in the MPI score means it is unsuitable for the 30 per cent of patients with cIAI who do not undergo any source control procedure. In 2015, the World Society of Emergency Surgery (WSES) validated a sepsis severity score for patients with intra-

Table 2 Multivariable models adjusted for shrinkage

Predictor	Comparison	Odds ratio†
Mortality model		
Intercept, log odds ratio (s.e.)		−7.53(1.10)
Underlying pathology	Diverticular disease	1.00 (reference)
	Cancer	4.07 (1.58, 10.48)
	Postoperative complication	1.30 (0.46, 3.68)
	Other	2.04 (0.98, 4.21)
Source control	Surgical	1.00 (reference)
	Radiological drainage	0.33 (0.08, 1.30)
	No source control	1.58 (0.81, 3.09)
Age (years)	23.5–34.4	1.00 (reference)
	34.5–55.4	2.80 (1.91, 4.12)
	55.5–65.4	7.61 (3.57, 16.22)
	65.5–75.4	14.49 (5.34, 39.29)
	75.5–85.4	27.59 (8.00, 95.17)
	85.5-95.5	52.54 (11.98, 230.49)
Perforated viscus	No	1.00 (reference)
	Yes	2.40 (0.94, 6.11)
Relapse model		
Intercept, log odds ratio (s.e.)		−2.30(0.35)
Collection(s) present	No	1.00 (reference)
	Yes	1.72 (0.93, 3.17)
Duration of antibiotics (days)	<5	1.00 (reference)
	5–7	4.71 (0.90, 24.59)
	8–11	6.82 (0.88, 52.85)
	12–17	7.86 (0.87, 70.85)
	18–41	8.65 (0.87, 86.37)
	>41	8.87 (0.86, 91.07)
Failure of initial management	No	1.00 (reference)
	Yes	5.27 (2.96, 9.40)

Values in parentheses are 95 per cent c.i. unless indicated otherwise. †Adjusted for shrinkage based on the median optimism-adjusted calibration slope.

Table 3 Scoring system for probability of death after treatment of complicated intra-abdominal infection

	Points
Age (years)	
<34.5	−3
34.5–55.5	−2
55.5–65.5	0
65.5–75.5	1
75.5–85.5	2
>85.5	3
Perforated viscus	1
Type of source control performed	
Percutaneous drainage	−2
Surgical	0
None	1
Aetiology of cIAI	
Cancer	2
Diverticular disease	0
Postoperative complication	0
Other	1

cIAI, complicated intra-abdominal infection.

abdominal infection[4]. A prospective multicentre observational study found that the WSES score was useful in predicting survival (mortality rate 0.63 per cent for score 0–3 and 41.7 per cent for score above 7)[4]. This model includes sepsis severity, origin of cIAI, setting of cIAI acquisition, immunosuppression, age, and time to source control as predictors. Model performance measures were not reported. These models are generally applied in research studies, rather than clinically.

In the present study, the observed mortality rate was 11.3 per cent and the rate of cIAI relapse was 17.3 per cent. The predictors identified for cIAI relapse and those for mortality were different, with the predictors for mortality comprising largely non-modifiable risks. cIAI relapse was not associated with significantly increased mortality; however, it was associated with antimicrobial resistance, longer duration of antibiotic treatment, and increased length of hospital stay.

In this cohort, 7.7 per cent of patients had an ESBL- or AmpC-producing organism isolated, similar to values reported in a European cohort[17]. Antimicrobial resistance was associated with a near doubling of the relapse rate, from 19.3 per cent to 33.3 per cent. This highlights that ongoing monitoring for the presence of antimicrobial-resistant bacterial infection should be considered important in optimizing the care of patients with cIAI.

This study does have limitations. First, the number of outcome events was small and this restricted the number of variables included in the pool of potential predictors for the multivariable logistic regression model. Second, data for several variables were missing; however, multiple imputation was conducted to mitigate for this. Third, data were collected at a local level and the validity of the data provided was not audited. Fourth, some relevant clinical data, such as severity of sepsis, placement of drains and duration of drainage, were not collected. Fifthly in the no-relapse group, patients who died were not excluded from the analysis when developing the relapse model. However, there were near equal proportions of patients who had died in the group that had a relapse and the group that did not, and so the interpretation of the results was deemed appropriate. Finally, although point scoring systems facilitate the use of prediction models, they are able to provide only approximate predictions of risk compared with the full models, and so are less accurate[16]. However, the clinical predictors selected to be included in the final models were consistent with those described in the literature.

Table 4 Estimate of risk based on score for mortality

Score	Estimate of risk of death after cIAI treatment (%)
−5	0.1
−4	0.2
−3	0.4
−2	0.7
−1	1.4
0	2.6
1	4.8
2	8.7
3	15.4
4	25.8
5	39.8
6	55.7
7	70.6

cIAI, complicated intra-abdominal infection.

Table 5 Scoring system for probability of relapse after treatment of complicated intra-abdominal infection

Predictor category	Points
Treatment failure*	3
Collection(s) present	1
Duration of antibiotics (days)	
<5	−6
5–7	−1
8–41	0
>41	1

* Defined as requiring an additional unplanned source control procedure or a change of antibiotics due to either failure of antibiotic treatment or presence of resistance.

Table 6 Estimate of risk of relapse after treatment of complicated intra-abdominal infection based on score

Score	Estimate of risk of relapse after cIAI treatment (%)
−6	0.3
−5	0.5
−4	0.9
−3	1.4
−2	2.5
−1	4.1
0	6.9
1	11.3
2	17.9
3	27.2
4	39.1
5	52.4

cIAI, complicated intra-abdominal infection.

The presented CPMs and subsequent scoring systems have advantages over existing ones because they provide information on both the risk of cIAI relapse and mortality. For these scoring systems, clinical data collected at the point at which management of the cIAI has been completed are used to predict outcomes at the end of treatment for cIAI. Therefore, they can guide decisions on patient follow-up or the need for further intervention at a clinically relevant time. They are simple to use and based on easily accessible patient data. Furthermore, they can be used for all patients who have a cIAI, irrespective of whether they undergo source control procedures.

This study has highlighted that, in the UK, there is variation in the management of cIAIs. One-third of patients do not undergo a source control procedure and durations of antibiotic treatment are, on average, longer than those recommended in guidelines[1,18]. This is likely due to the high complication rate seen in this cohort. These prediction models can help identify patients with a high risk of complications, in whom deviation from guidelines may be warranted. Future work will involve the validation of both prediction models, and their integer score versions, in external data from existing cIAI studies. After this assessment of external validity via discrimination and calibration, clinical utility studies will be considered.

Collaborators

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